

# Annex F

## Methodology for Estimating Methane Emissions from Petroleum Systems

The methodology for estimating methane emissions from petroleum systems is being updated. EPA anticipates that current methodology understates emissions, and that the new methodology will be incorporated into future inventories.

### Step 1: Production Field Operations

The American Petroleum Institute (API) publishes active oil well data in reports such as the *API Basic Petroleum Data Book*. To estimate activity data, the percentage of oil wells that were not associated with natural gas production, averaging approximately 56.4 percent over the period 1990 through 1996, was multiplied by the total number of wells in the United States. This number was then multiplied by per well emission factors for fugitive emissions and routine maintenance from Tilkicioglu & Winters (1989). Table F-1 displays the activity data, emission factors, and emissions estimates used.

### Step 2: Crude Oil Storage

Methane emissions from storage were calculated as a function of annual U.S. crude stocks less strategic petroleum stocks for each year, obtained from annual editions of the *Petroleum Supply Annual* (EIA 1991, 1992, 1993, 1994, 1995, 1996, 1997). These stocks were multiplied by emission factors from Tilkicioglu & Winters (1989) to estimate emissions. Table F-2 displays the activity data, emission factors, and emissions estimates used.

### Step 3: Refining

Methane emissions from refinery operations were based on U.S. refinery working storage capacity, found in annual editions of the *Petroleum Supply Annual* (EIA 1991, 1992, 1993, 1994, 1995, 1996, 1997). This capacity was multiplied by an emission factor from Tilkicioglu & Winters (1989) to estimate emissions. Table F-3 provides the activity data, emission factors, and emissions estimates used.

### Step 4: Tanker Operations

Methane emissions from the transportation of petroleum on marine vessels were estimated using activity data on crude oil imports, U.S. crude oil production, Alaskan crude oil production, and Alaskan refinery crude oil capacity. All activity data were taken from annual editions of the *Petroleum Supply Annual* (EIA 1991, 1992, 1993, 1994, 1995, 1996, 1997).

Tilkicioglu & Winters (1989) identified three sources of emissions in the transportation of petroleum. These are emissions from loading Alaskan crude oil onto tankers, emissions from crude oil transfers to terminals, and ballast emissions.

#### Step 4.1: Loading Alaskan Crude Oil onto Tankers

The net amount of crude oil transported by tankers was determined by subtracting Alaskan refinery capacity from Alaskan crude oil production. This net amount was multiplied by an emission factor from Tilkicioglu & Winters (1989) to estimate emissions. The activity data and emissions estimates are shown in Table F-4.

#### Step 4.2: Crude Oil Transfers to Terminals

Methane emissions from crude oil transfers were taken from the total domestic crude oil transferred to terminals. This amount was assumed to be 10 percent of total domestic crude oil production less Alaskan crude oil production.

To estimate emissions, this transferred amount was multiplied by an emission factor from Tilkicioglu & Winters (1989). The activity data and emissions estimates are shown in Table F-5.

### Step 4.3: Ballast Emissions

Ballast emissions are emitted from crude oil transported on marine vessels. This amount was calculated from the sum of Alaskan crude oil on tankers, the amount of crude oil transferred to terminals, and all crude oil imports less Canadian imports. Ballast volume was assumed to be 17 percent of this sum (Tilkicioglu & Winters 1989). This amount was then multiplied by an emission factor to estimate emissions. The activity data and emissions estimates are shown in Table F-6.

Total emissions from tanker operations are shown in Table F-7.

### Step 5: Venting and Flaring

Methane emissions from venting and flaring were based on 1990 emissions estimates from EPA (1993) and were held constant through 1996 due to the lack of data available to assess the change in emissions.

Table F-1: Emissions from Petroleum Production Field Operations

Activity	Units	1990	1991	1992	1993	1994	1995	1996
Total Oil Wells		587,762	610,204	594,189	583,879	581,657	574,483	574,419
% Not Assoc. w/ Natural Gas	%	55.6%	56.4%	56.7%	56.7%	56.6%	56.7%	56.5%
Oil Wells in Analysis		326,982	343,873	336,749	330,843	329,366	325,451	324,362
<b>Emission Factors</b>								
Fugitive	kg/well/yr	72						
Routine Maintenance	kg/well/yr	0.15						
<b>Emissions</b>								
Fugitive	mill kg/yr	23.5	24.8	24.3	23.9	23.7	23.4	23.4
Routine Maintenance	mill kg/yr	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table F-2: Emissions from Petroleum Storage

Activity	Units	1990	1991	1992	1993	1994	1995	1996
Total Crude Stocks	1000 barrels/yr	908,387	893,102	892,864	922,465	928,915	894,968	849,669
Strategic Petroleum Stocks	1000 barrels/yr	585,692	568,508	574,724	587,080	591,670	591,640	566,000
Crude Oil Storage	1000 barrels/yr	322,695	324,594	318,140	335,385	337,245	303,328	283,669
<b>Emission Factors</b>								
Breathing	kg CH <sub>4</sub> /brl/yr	0.002612						
Working	kg CH <sub>4</sub> /brl/yr	0.002912						
Fugitive	kg CH <sub>4</sub> /brl/yr	4.99x10 <sup>-5</sup>						
<b>Emissions</b>								
Breathing	kg/yr	842,892	847,853	830,994	876,039	880,897	792,305	740,955
Working	kg/yr	939,602	945,131	926,339	976,552	981,968	883,210	825,969
Fugitive	kg/yr	16,118	16,213	15,891	16,752	16,845	15,151	14,169
<b>Total Emissions</b>	<b>mill. kg/yr</b>	<b>1.80</b>	<b>1.81</b>	<b>1.77</b>	<b>1.87</b>	<b>1.88</b>	<b>1.69</b>	<b>1.58</b>

Table F-3: Emissions from Petroleum Refining

Activity (Jan 1)	Units	1990	1991	1992	1993	1994	1995	1996
Total Refinery Storage Capacity	1000 barrels/yr	174,490	171,366	167,736	170,823	164,364	161,305	158,435
Storage Emission Factor	Mg CH <sub>4</sub> /brl/yr	5.9 x 10 <sup>-5</sup>						
Emissions	mill. kg/yr	10.29	10.10	9.89	10.07	9.69	9.51	9.34

Table F-4: Emissions from Petroleum Transportation: Loading Alaskan Crude Oil onto Tankers (Barrels/day\*)

Activity	1990	1991	1992	1993	1994	1995	1996
Alaskan Crude	1,773,452	1,798,216	1,718,690	1,582,175	1,558,762	1,484,000	1,393,000
Alaskan Refinery Crude Capacity	229,850	239,540	222,500	256,300	261,000	275,152	283,350
Net Tankered	1,543,602	1,558,676	1,496,190	1,325,875	1,297,762	1,208,848	1,109,650
Conversion Factor (gal oil/ barrel oil)	42						
Emission factor (lbs/gallon)	0.001						
Emissions @ Loading AK (lbs/day)	64,831	65,464	62,840	55,687	54,506	50,772	46,605
Methane Content of Gas (%)	20.80%						
Emissions @ Loading AK (mill kg/yr)	2.23	2.26	2.17	1.92	1.88	1.75	1.61

\* Unless otherwise noted

**Table F-5: Emissions from Petroleum Transportation: Crude Oil Transfers to Terminals (Barrels/day\*)**

Activity	1990	1991	1992	1993	1994	1995	1996
US Crude Production	7,355,307	7,416,545	7,190,773	6,846,666	6,661,578	6,560,000	6,465,000
AK Crude Production	1,773,452	1,798,216	1,718,690	1,582,175	1,558,762	1,484,000	1,393,000
US Crude - AK Crude	5,581,855	5,618,329	5,472,082	5,264,490	5,102,816	5,076,000	5,072,000
10% transported to terminals	558,185	561,833	547,208	526,449	510,282	507,600	507,200
Conversion Factor (gal oil/ barrel oil)	42						
Emission factor (lbs/gallon)	0.001						
Emissions from Transfers (lbs/day)	23,444	23,597	22,983	22,111	21,432	21,319	21,302
Methane Content of Gas (%)	20.80%						
Emissions from Transfers (mill kg/yr)	0.81	0.81	0.79	0.76	0.74	0.73	0.73

\* Unless otherwise noted

**Table F-6: Emissions from Petroleum Transportation: Ballast Emissions (Barrels/day\*)**

Activity	1990	1991	1992	1993	1994	1995	1996
Crude Imports (less Canadian)	5,251,701	5,038,786	5,300,616	5,886,921	6,079,773	6,125,482	6,909,429
Alaskan Crude (Net Tankered)	1,543,602	1,558,676	1,496,190	1,325,875	1,297,762	1,208,848	1,109,650
10% Crude Prod. Transported to terminals	558,185	561,833	547,208	526,449	510,282	507,600	507,200
Conversion Factor (gal oil/ barrel oil)	42						
Emission factor (lbs/1000 gallons)	1.4						
Crude Oil Unloaded	7,353,489	7,159,296	7,344,015	7,739,245	7,887,816	7,841,930	8,526,279
Ballast Volume							
(17% of Crude Unloaded)	1,250,093	1,217,080	1,248,483	1,315,672	1,340,929	1,333,128	1,449,467
Ballast Emissions (lbs/day)	73,505	71,564	73,411	77,361	78,847	78,388	85,229
Methane Content of Gas (%)	20.80%						
Ballast Emissions (mill kg/yr)	2.53	2.47	2.53	2.67	2.72	2.70	2.94

\* Unless otherwise noted

**Table F-7: Total Methane Emissions from Petroleum Transportation**

Year	Million kg/yr
1990	5.6
1991	5.5
1992	5.5
1993	5.4
1994	5.3
1995	5.2
1996	5.3